DEVELOPMENT OF ELECTRODYNAMICS TRANSDUCER FOR SOLID PARTICLE MEASUREMENT

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ABSTRACT

The electrostatic sensor was used in process industry because low cost and robust. Electrostatic charge can be detected using sensing device or called as electrode sensor and convert into voltage using associated electronic or known as electrodynamics transducer.The sensing device or electrode sensor consists of a conductor, insulated from the pipeline which may take a variety of different shapes and sizes. The associated electronics is a circuit for signal conditioning to invert the voltage. In the pipeline system, non-intrusive electrode sensor was assembled or implemented. Movement of solid particles which is sand will generate electrostatic charges and can be detect using sensing device or electrode and convert into voltage by electrodynamics transducer or associated electronic. The pipeline system will develop for solid particle flow and the electrodynamics transducer for signal conditioning circuit. The three outputs are amplified voltage, rectified voltage and average voltage will captured and analysis by oscilloscope.

ABSTRAK

Pengesan elektrostatik telah digunakan dalam proses industry kerana kos rendah dan tidak berubah-ubah. Cas electrostatik boleh dikesan menggunakan peranti pengesan atau dipanggil sebagai elektrod pengesan dan ditukar kepada voltan oleh gabungan elektronik atau dikenali sebagai electrodinamika transduser. Peranti pengesan mengandungi konduktor, yang tidak bersambung dengan saluran paip yang mana terdapat dalam pelbagai saiz dan bentuk. Manakala, gabungan elektronik terdapat litar untuk isyarat keadaan. Di dalam saluran paip, elektrod pengesan yang tidak mengganggu dipasang. Pergerakan zarah pepejal akan menghasilkan cas-cas elektrostatik yang mana akan dikesan oleh peranti pengesan atau elektrod dan ditukar kepada voltan menggunakan electrodinmika transduser atau gabungan elektronik. Saluran paip direka untuk laluan zarah pepejal dan litar electrodinamika transduser direka utntuk litar isyarat keadaan. Tiga keputusan yang diperolehi adalah voltan penguat, voltan pembetul, dan voltan purata dan disahkan dan dianalisis dengan osiloskop.

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LIST OF SYMBOLS

+	Plus sign
-	Minus sign
n	Nano sign
pF	Piko Farad Sign
μ	Mikro Sign
M	Mega sign
K	Kilo sign
E	Electric field sign
Q	Charge Sign
ε_0	Permitivity of free space sign

LIST OF ABBREVIATIONS

D	Diode
GND	Ground
AC	Alternate current

CHAPTER 1

INTRODUCTION

1.0 Background of Project

The development of this project is to design an electrodynamics transducer for solid particle measurement. Electrodynamics transducer or called as associated electronic consists of circuit for signal conditioning and the electrodes or sensing device consists of a conductor, insulated from the pipeline which may take a variety of different shapes and sizes[4,7]. Movement of solid particles in pipeline generates an electrostatic charge which is can be detected by using electrode or sensing device and converted into voltage by the electrodynamics transducer or associated electronics. Many processes in industries require continuous,smooth and consistent delivery of solids particle.In order to achieve those requirement, a proper measurement need to be install. Electrodynamics transducer offers the most inexpensive and simplest means of measuring solids flows in pipe. Besides that, electrodynamics transducer are widely used in industries because robust and low cost implementation in measurement. Application that applicable are process tomography, particle size processing and soil properties determination. But, some problem might occur such as poor throughput excessive power consumption , blockages caking and product degradation.

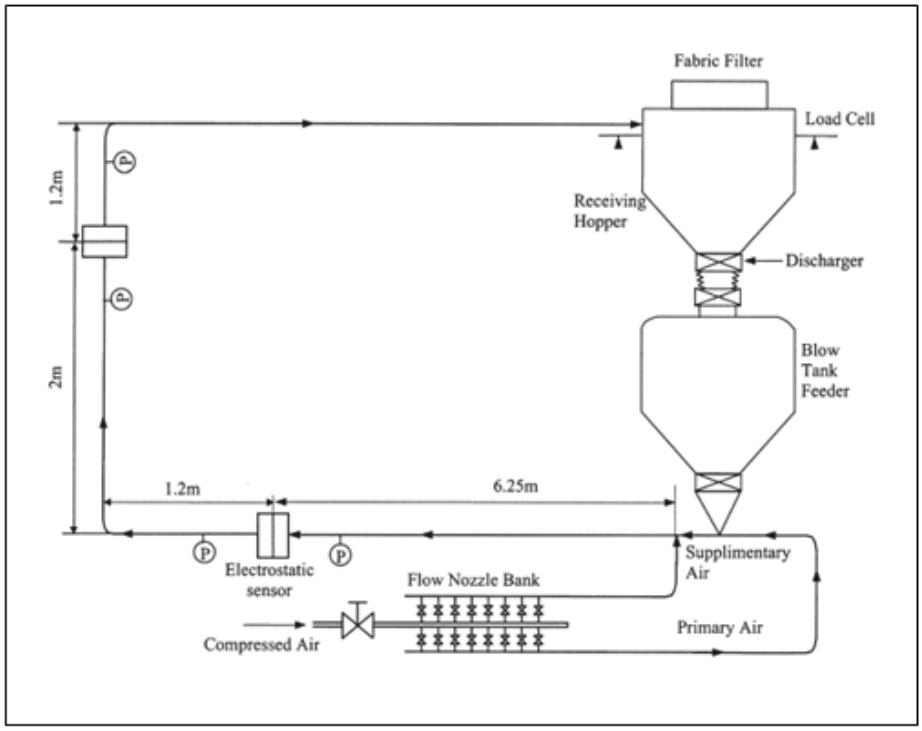

Figure 1.1: Process in industry

Solid particles flowing in a pipeline is a common mode of transport in industries. This is because pipeline transportation can avoid waste through spillage and minimizes the risk of handling of hazardous materials. Pharmaceutical industries, food stuff manufacturing industries, cement, and chemical industries are a few industries to exploit this transportation technique. For such industries, monitoring and controlling material flow through the pipe is an essential element to ensure efficiency and safety of the system. The purpose of this paper is to present electrical charge tomography, which is one of the most efficient, robust, cost-effective, and non-invasive tomography methods of monitoring solid particles flow in a pipeline. The figure 1.2 the assemble of electrode sensor in industry. There are three type of electrode sensor which are, ring shape, pin shape and quarter ring shape. The ring shape is widely used but it needs a lot of cost and hard to implement. The figure 1.3 was the process test rig which is for two types of coal: Colombian Coal(CC) and South Africa coal (SA), Biomass additions of 0%, 5%, 10%, 15%, and 20% were tested by premixing with the SA before milling [2]. The biomass fuel was dried sawdust pellets from the furniture manufacturing industry.

The coal samples were stored in open air prior to the tests and hence had high moisture content due to rainfall.

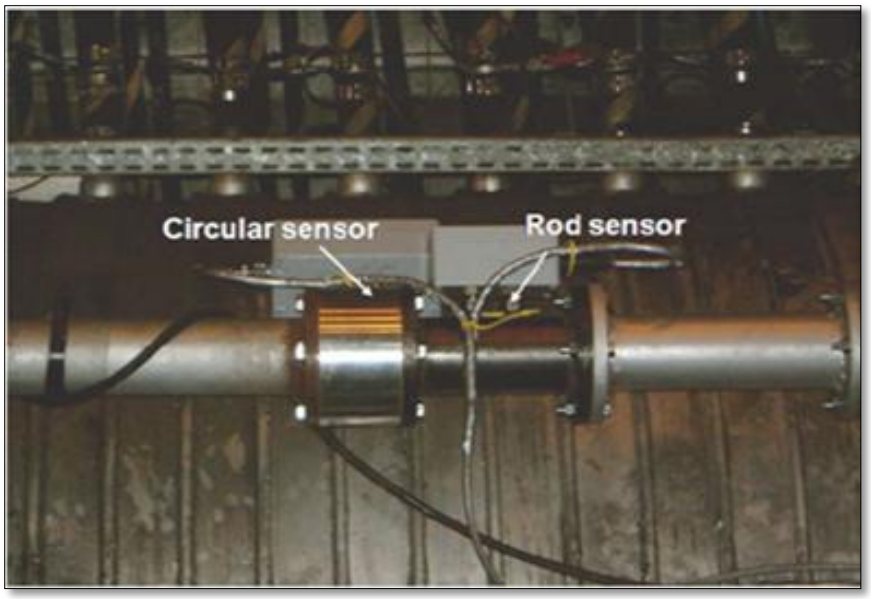

Figure 1.2: Installation of electrostatic sensor

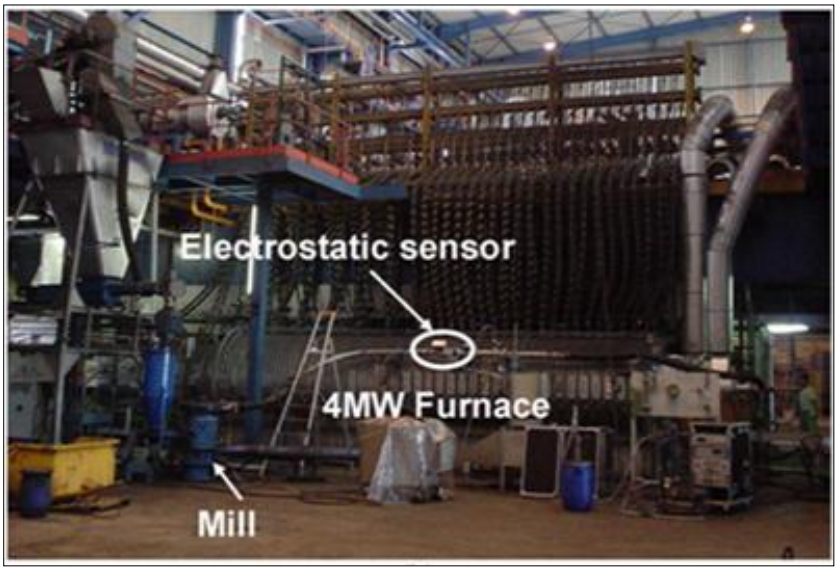

Figure 1.3: Overview the combustion test rig

The key design of this method is electrostatic transducer and solid particle. Sand was used as solid particle because the particles in sand were much closed and

they cannot move but vibrate in fixed position. The block diagrams of a sensing system as shown in figure 1.The other term which refer to electrodynmic are electrostatic and triboelectric. ‘Electrodyamic’ refers to the fact that the change arose from the movement of particles. ‘Triboelectric’ emphasized that the particles are charged due to the friction or direct contact between the particles and the electrode. ‘Electrostatic’ implies the electrosatic nature of the sensing principle of the sensor.

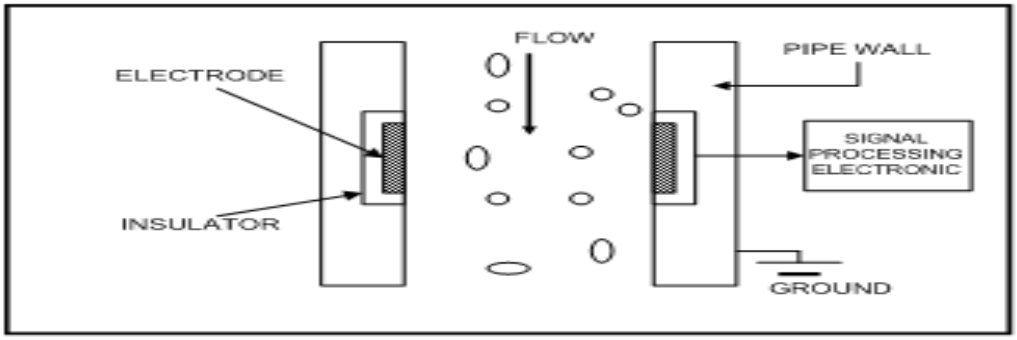

Figure 1.4: The Block Diagram of an Electrostatic Sensing System

This project can be used in food manufacturing industry by implemented the electrostatic sensor. Once the food cross the electrode sensor, the system automatically can count, and identify the size of packaging. It is also can be applied in electronic component.

1.2 Objectives of project

The main objective of this project is to develop electrodynamics transducer for solid particular measurement. The specific objectives of this project are listed below:

i. Develop non-intrusive pipeline system for solid particle measurement

ii. Design of circuit electrodynamics transducer.

iii. Analysis the three signal waveform which are amplified voltage, rectifier voltage and average voltage.

1.3 Scope of Project

The scopes of project based on the development of electrodynamics transducer are:

i. Design the pipeline system consist three different sizes of electrodes which are 8mm, 13mm, and 14mm.

ii. Design electrodynamics transducer circuit to detect electrostatic charge and convert into voltage.

iii. Capture the three signal outputs which are amplified voltage, rectified voltage and averaged voltage.

1.4 Thesis Overview

This thesis consists of five chapters and each chapter will in details about this project including introduction, literature review, methodology, result and analysis, and conclusion.

The first chapter, it is discuss about the basic idea of this project which is based on electrodynamics transducer. The main concept is about to develop non intrusive pipeline and design the electrodynamics transducer circuit.

Literature review chapter consists of the explanation about the movement particle in pipeline and how its generate charge, about the circuit conditioning and the method use to get the voltage signal.

Furthermore, detail explanation in methodology about the design will be presented. Each step will be explains more detail in order to get the desired output. But, the important things, the charge detect by the electrode sensor and convert into voltage.

In addition, result and analysis in this project will shown in chapter 4 either achieved the goal or not.

Last but not least, is on conclusion and recommendation of this project. This chapter, will summarize about the whole step had be done and give better recommendation for better performance and result.

CHAPTER 2

LITERATURE REVIEW

2.1 Electrostatic

Electrostatics involves the buildup of charge on the surface of objects due to contact with other surfaces. Although charge exchange happens whenever any two surfaces contact and separate, the effects of charge exchange are usually only noticed when at least one of the surfaces has a high resistance to electrical flow. This is because the charges that transfer to or from the highly resistive surface are more or less trapped there for a long enough time for their effects to be observed. These charges then remain on the object until they either bleed off to ground or are quickly neutralized by a discharge: e.g., the familiar phenomenon of a static 'shock' is caused by the neutralization of charge built up in the body from contact with nonconductive surfaces[15]. Example of the electrostatic phenomena is the attraction of the plastic wrap to your hand after removes it from package.

An electric charge near a metal object cause the mobile charges in the metal to separate. If the external charge is positive as shown in figure 2.1, negative charge are attracted and move to the surface object. Electrostatic field line cannot penetrate conductive object; they always end of induced charges o surface[15].

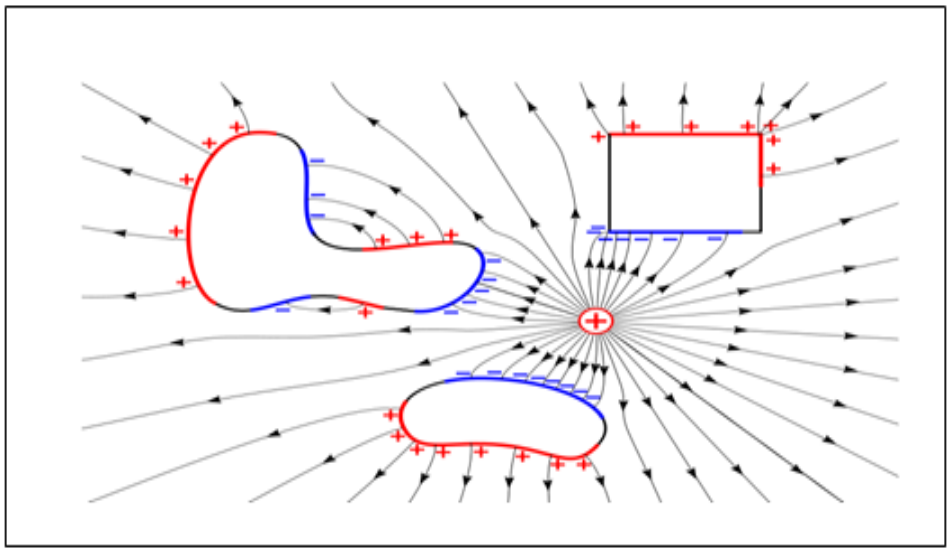

Figure 2.1: Diagram of charge induced in conductive object.

From this definition and Coulomb's law, it follows that the magnitude of the electric field *E* created by a single point charge *Q* is:

$$E = \frac{Q}{4\pi r^2 \varepsilon_0}$$

Where E is the electric field, ε_0 is the permittivity of free space (8.854×10^{-12}F/m), and R is the distance between the charged particle and a particular point.

2.2 Electrode Sensor

A number of different shapes of electrode e have been used as sensing elements for the flow measurement stud (pin) electrode, quarter ring electrode, and ring electrode [9]. Figure 2.2 show the type of electrode. Ring electrode is widely used process industry but it is no longer applicable, because it is difficult to install, costly and often impractical for large pipeline in inconvenient locations. Besides that, this ring shape is most sensitive to particulate near the pipeline wall. However, pin

electrodes which consist of circular and rectangular shapes had been thoroughly investigated. In this project, circular electrode sensor was used. Figure 2.3 show the shape of pin electrode.

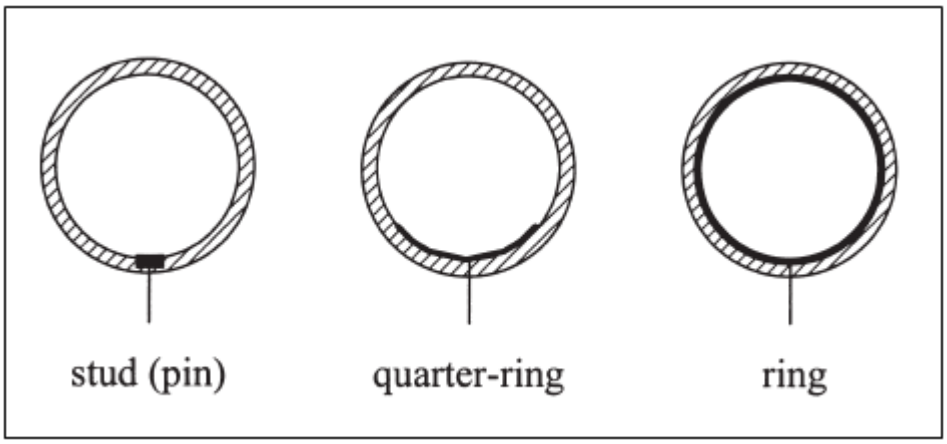

Figure 2.2: Electrodes used in electrode sensor

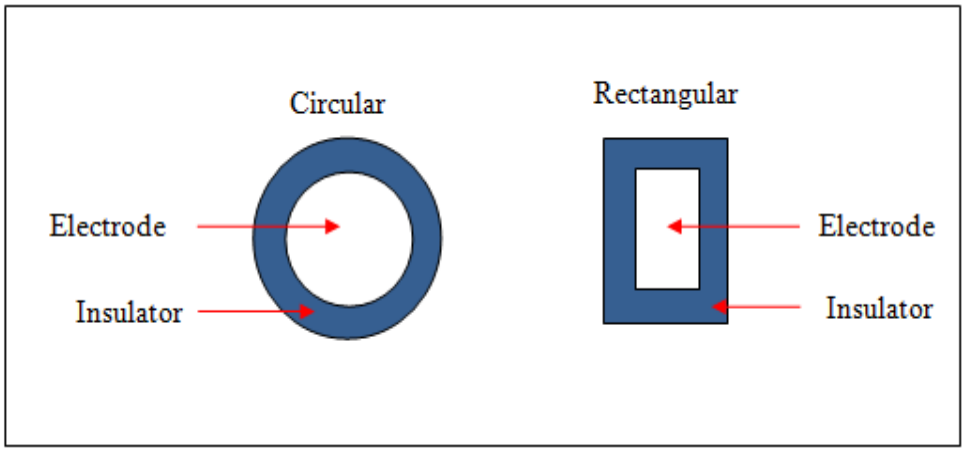

Figure 2.3: Pin electrode

There are two ways how to implement the electrode sensor in pipeline which are called intrusive electrode or non-intrusive electrode. Since, the intrusive electrode extends into the particle flow, it can "sample" the flow conditions along the cross section, particularly if several such electrodes are positioned around the perimeter of the pipeline. Intrusive electrodes will cause a disturbance to the particle itself. In

addition, it may be of concern that particles striking the upstream electrode will lose some of their velocity, affecting the sensor measurement [2]. However, in striking the upstream electrode, the particle will release its charge; no signal will be induced on the downstream electrode.

Non-intrusive electrode was used in this project to detect the electrostatic charges; means the electrode sensor was implemented align with the pipe wall. Thus, only the surface of electrode was exposed to the solid particle and will not disturb the flow it. Figure 2.4 show, the way to implement the sensor electrode.

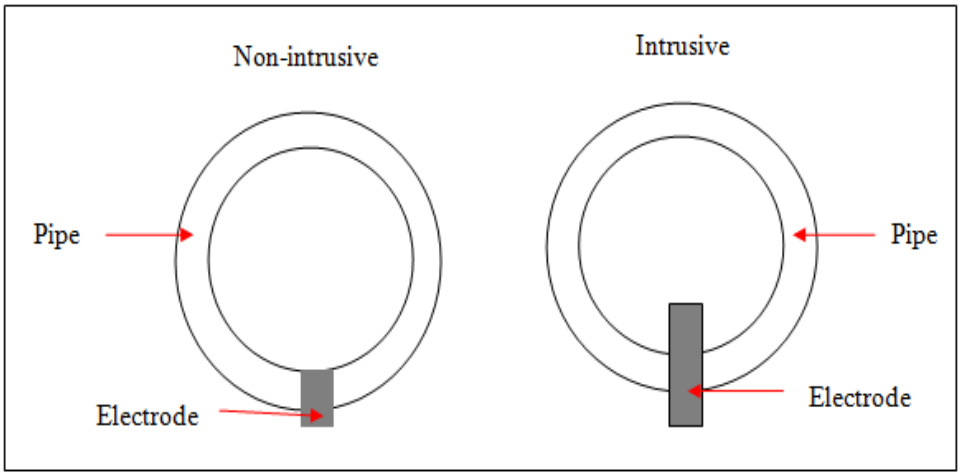

Figure 2.4: Implemented of electrode sensor

Moreover, the pipe wall was isolated from the sensor electrode by putting the insulator which is rubber. If the electrode is exposed directly to solid particle, direct change transfer due to the contact between the particle and the electrode can take place. However, if the axial dimension of an exposed electrode is small compared to the pipe diameter, electrostatic induction will be the dominant interaction [9].

2.3 Electrodynamics Transducer

The circuit diagram of the electrodynamics transducer is shown in figure 2.6. the transducer consist of plain metal rod , termed the electrode which capacitance to the earth and connected to the signal conditioning circuit. A resistor is connected in parallel to the capacitor to provide charge or discharge path. The charged particles in the pipe flow past the electrode including charge into it in the process [5]. The flow of current will provide a varying voltage. This voltage will buffer by non-inverting amplifier whose output will be input circuitry and is amplified and conditioned by further circuitry.

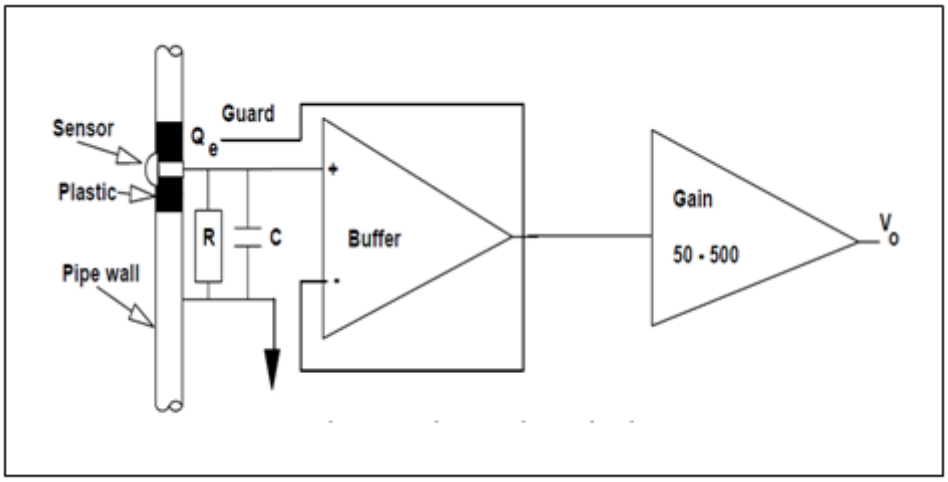

Figure 2.5: Transducer circuit.

Figure 2.6 show the block diagram of electrostatic transducer circuit [13]. The AC generate voltage will be the input for the non inverting voltage follower. Then, the output of this stage is used as guard voltage for input circuitry and is AC coupled to the input of the non-inverting voltage amplifier. The output 1 was AC amplified voltage, output 2 AC rectifier voltage and output 3 average voltage.

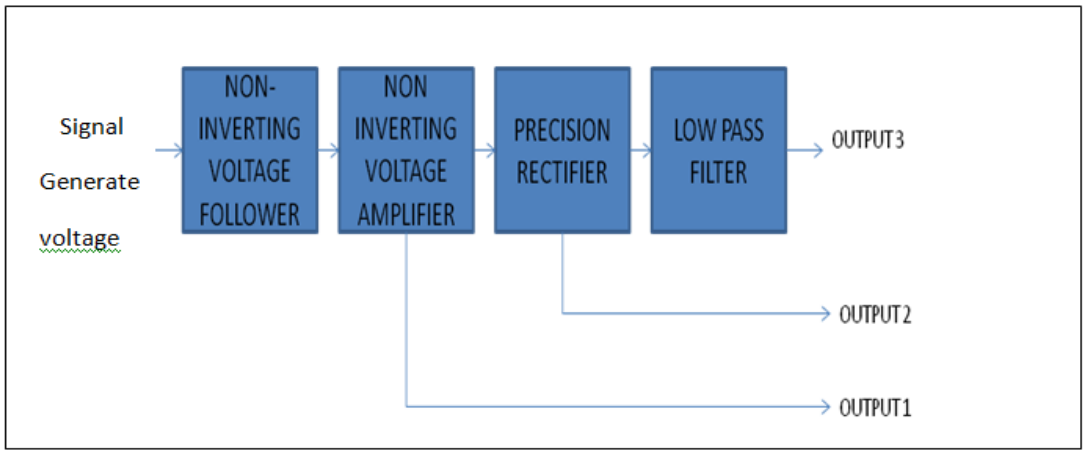

Figure 2.6: Block diagram of electrodynamics transducer circuit

The configuration of non-inverting voltage amplifier, the input voltage signal, (Vin) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes positive in value in contrast to the "Inverting Amplifier" circuit. The result of this is that the output signal is "in-phase" with the input signal. Then, rectifier circuits are used in the design circuits. In such applications, the voltage being rectified usually much greater than the diode voltage drop. Only the positive-going portions of the output waveform, which correspond to the negative-going portions of the input signal, actually reach the output. The direct feedback diode shunts any negative-going output back to the "-" input directly, preventing it from being reproduced.

2.4 Pipeline System

In order to get the accurate charge without distortion, make sure no corrosion happen in the pipeline. If the electrode embedded inside the pipeline so that there is o direct contact between the particle and the electrode [9] In contrast, if the electrode is exposed directly to the particles and the electrode can take place. The figure 2.7: show the overall of design pipeline: hardware.

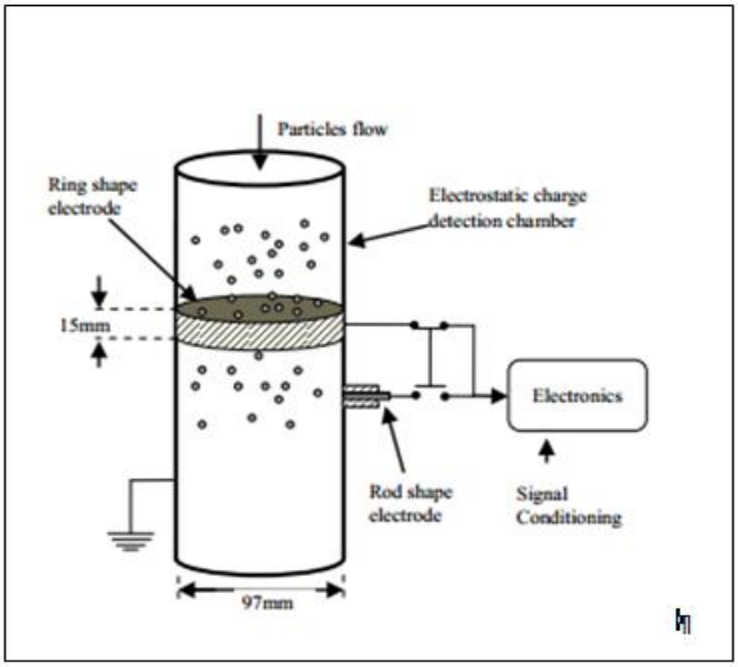

Figure 2.7: design of pipeline system

Figure 2.8 shows a picture of applied test rig; it is consist of a particles bunker in the top, rotary feeder to control mass flow rate in the pipe and a vacuum loader which refill the bunker [14]. Plastic bead was used as solid particle. The plastic bead will flow through the pipeline system and the flow rate of plastic was control by the rotary feeder. The measurement system begin when electrical charge detected by electrostatic sensor. Electrostatic sensor converts the detected signal to an AC voltage and then this signal is sampled by 1 kHz sampling frequency using an A-to-D signal converter. And converted signal is applied in computer software to extract mass flow rate and concentration profile. The pump will suck plastic bead, from the vacuum load automatically and the process will continuously.

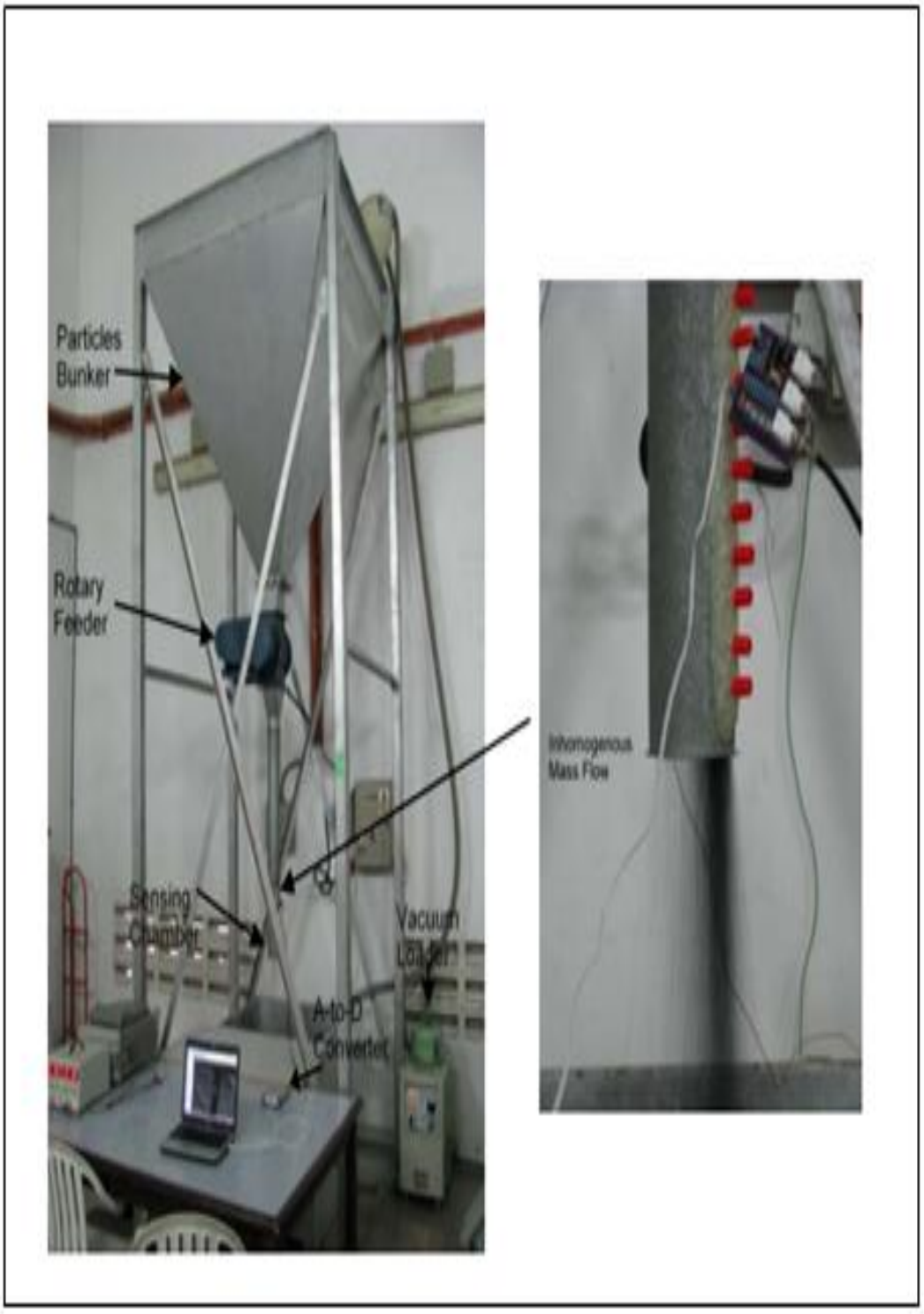

Figure 2.9: Test rig process

In this project, the solid will used is sand and the system is not run automatically which is, the solid particle flow manually.